South Asian Network for Development and Environmental Economics

SANDEE
PO Box 8975 EPC 1056
Kathmandu, Nepal

Tel: 977-1-552 8761
Fax: 977-1-553 6786
E-mail: info@sandeeonline.org
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Taxing the Pollution: A Case for Reducing the Environmental Impacts of Rubber Production in Sri Lanka

Jagath Edirisinghe, Susantha Siriwardana,
Sarath Siriwardana and Punsara Prasandith

South Asian Network for Development and Environmental Economics

March 2008

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JAGATH EDIRISINGHE, SUSANTHA SIRIWARDANA, SARATH SIRIWARDANA AND PUNSARA PRASANDITH

Department of Agribusiness Management,
Wayamba University, Sri Lanka

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Technical Editor
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Comments should be sent to Jagath Edirisinghe, School of Agriculture, Policy and Development, University of Reading, UK. Email:jagathed@yahoo.com

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Abstract

Most firms that process rubber in Sri Lanka do not comply with national water pollution control standards. This study seeks to estimate a pollution tax that could motivate firms to meet these standards. The authors use data from 62 rubber producing firms in Sri Lanka over three years to estimate a marginal cost function for pollution abatement. They then estimate the taxes that would bring firms into compliance. The tax rate necessary for environmental compliance is 26 Sri Lankan rupees per 100 grams of Chemical Oxygen Demand (COD) per year. While the burden of a pollution tax on the average firm would be 8.6% of annual turnover, the tax burden varies with the size of the firm. The authors suggest that the use of such an economic instrument might motivate the Central Environmental Authority to monitor effluents more carefully and firms to make use of effluents.

Key words: water pollution, effluent taxes, rubber industry, Sri Lanka

Taxing the Pollution: A Case for Reducing the Environmental Impacts of Rubber Production in Sri Lanka

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1. Introduction

Rubber is one of the most polluting industrial activities in Sri Lanka (Central Environmental Authority, 2000). More than half the estates that produce rubber release effluents generated by rubber processing directly into natural water streams (Yapa, 1984, Kudaligama, 2004). Water contaminated by rubber effluent cannot be used for any other domestic or industrial purposes (Kudaligama, 2004), and such effluents are also found to pollute groundwater (Dan et al., 2006; Kudaligama, 2004). Moreover, new residential areas have emerged in rubber-growing districts and this has added a new dimension to the environmental problem with an increasing number of complaints being recorded (Yapa, 1984). In response to the industrial, ecological and human problems some factories have closed down, others have either relocated or been ordered to urgently tackle their pollution issues (Science and Technology, 1999).

The present system of pollution control in Sri Lanka is through a command and control approach where strict environmental standards are set and monitored by Sri Lanka's Central Environmental Authority (CEA). The CEA enforces environmental standards for industrial effluents that are discharged into inland surface waters (Table 1). It has the right to initiate legal actions against firms that do not comply with these standards. Although, the CEA has identified the rubber industry as a significant polluter, until 1990 regulatory standards for pollutants was not available for rubber effluents (Ranaweera, 1991). Furthermore, enforcement is clearly lax because there is considerable evidence of water pollution by the rubber industry.

In the regulatory economics literature, there are numerous studies that compare the efficacy of command and control approaches over more market-oriented mechanisms for controlling water pollution (Hanley and Moffat, 1993; Pandey, 2005) as well as air pollution (Krupnick et al., 1983; McGartland and Oates, 1985; Krupnick, 1986). Generally, these market-oriented mechanisms refer to economic instruments such as taxes, permits and emission charges, which create an incentive for polluters to reduce pollution in lieu of paying penalties. There is now considerable evidence that supports market-based mechanisms rather than command and control strategies as pollution mitigating tools.

Within the studies that focus on water pollution, some have examined permits where each polluting firm can trade their 'right' to pollute (Hanley and Moffat, 1993), others have examined emissions charges or taxes (James and Murty, 1999; Dasgupta et al., 2001; Goldar et al., 2001), while still others have examined the role of informal regulation (Huq and Wheeler, 1993; Hartman et al., 1997 Pargal and Wheeler, 1996, Kathuria, 2004). The studies on water pollution have concentrated on diverse industries in different countries: the sugar industry (Murty et al., 2006) and distilleries in India (Goldar et al., 2001), food processing, textiles, paper, oil refining and chemical industries in China (Dasgupta et al., 2001), and organic water pollution industries in Indonesia (Pargal and Wheeler, 1996). The literature on the application of market-based instruments or informal regulation in Sri Lanka is however scarce.

Since in Sri Lanka command and control measures have thus far been unable to mitigate pollution, (Herath and Randeni, 2003), it is appropriate to investigate the feasibility of using other instruments such as pollution taxes. Thus, this study seeks to estimate the pollution tax rate for the rubber industry that would motivate polluting firms to meet current environmental standards. The underlying idea is that firms that do not meet environmental standards would decrease their pollution so that they can reduce their tax burden. In order to estimate pollution taxes, the study uses data from 62 firms to first estimate the marginal costs of pollution control to rubber firms. Based on this, it estimates the optimal tax rate, or the rate that equals the marginal cost of abatement when environmental standards are met. The study also examines the financial burden and distributional implications of establishing such a pollution tax.

2. The Rubber Industry and Water Pollution

Sri Lanka produces three main grades of raw natural rubber: Ribbed Smoked Sheets (RSS), Crepe Rubber (CR) and Centrifuged Latex (CL). The total natural rubber production in 2006 was 114,700 MT indicating an increase of 9 percent compared to the previous year (International Rubber Study Group (IRSG), 2007).

An average-sized rubber factory, which normally produces crepe rubber, produces 1.5-2 metric tonnes (MT) of raw rubber and discharges approximately 40-50 liters of effluent for every kilogram of rubber produced (Science and Technology, 1999). During 2006, a total of 114,700 metric tonnes (MT) of rubber was produced in Sri Lanka (IRSG, 2007); thus the industry discharged effluents totaling 4.5 to 5.7 billion liters in that year alone.

A given volume of rubber latex contains only 30-40 per cent of rubber, and the balance consists of serum substances. The serum is a clear yellowish liquid containing amino acids, carbohydrates and plant growth substances with lactic acid that is formed in the latex. In addition there are substances added to the latex such as sodium sulphite, ammonia or formalin in the field. Formic, acetic, oxalic acid or a combination of these is added to coagulate the latex. Other substances such as sodium bisulphite, metabisulphite or xylyl mercaptan are used to improve the quality of rubber. After coagulation, this serum is drained out of the factory as effluent. In addition to these chemical residues, the rubber effluent consists of various non-rubber constituents such as carbohydrates, proteins and amino acids and un-coagulated rubber particles, all of which are classified as environmental pollutants.

Most of the rubber factories do not have facilities to treat the effluent prior to disposal and hence it is customary to discharge untreated effluent into neighboring surroundings causing severe environmental pollution (Yapa, 1984). This discharge of effluent water into streams adversely affects their water quality, making them unsuitable for human consumption because the parameters of rubber effluent are found to be outside the general tolerance limits set out by the CEA (Table 2). In addition, Chemical Oxygen Demand (COD) levels of more than 500mg/l are reported to be found in waters where effluent is discharged, even up to a kilometer away from the factory although the maximum tolerance limit set by CEA is 400 mg/l (Kudaligama, 2004).

3. Taxing Pollution

Many production processes yield byproducts, which unlike the primary product, are not sold and often not safely disposed. Usually, such a byproduct is released and assimilated into the environment with little or no cost to the producer. The cost to society and the environment, however, can be considerable. Over the years, economists have devised a variety of policy instruments to motivate polluters to internalize these costs and reduce pollution. One such instrument is a Pigouvian tax. If a Pigouvian tax is in place, the polluter has to make a decision between either cleaning the effluent or paying a tax on pollution. The decision on the extent to which the cleaning should be done emerges from equating the tax rate per unit of effluent to the cost per unit of effluent abatement (James and Murty, 1999).

The idea of how a tax can be used to control pollution is depicted in Figure 1. If the Marginal Abatement Cost (MAC) for the producer is known and the pollution standard is specified at 'S', then the tax rate that is required to achieve the standard is T. However, as is clear from Figure 1, to identify the correct tax rate, it is necessary to know the shape of the MAC. Thus, an important first step in establishing a tax to reduce rubber pollution in Sri Lanka is the estimation of a MAC function.

The marginal abatement cost function is generally estimated in two ways. The first approach is to econometrically estimate the total abatement cost function using plant level data and then estimate the MAC (Murty et al., 2006; Goladar and Pandey, 2001). Others have estimated shadow prices for pollutants through the estimation of an output distance function, which is used to develop a pollutant specific MAC (Murty et al., 2006; Murty and Kumar, 2002; Marklund, 2003). Both these techniques have been equally adopted in past studies.

In this study, we adopt the econometric approach of estimation. Following James and Murty (1999) and Dasgupta et al. (2001), the total abatement cost function is defined as

$$C_j = f(W_j, \frac{E_{ji}}{I_{ji}}, M_s, X_j) \text{ ------------------------------- } (1)$$

Where,

C_j = Total annual cost of abatement for the j^{th} plant

W_j = Total annual wastewater volume of the j^{th} plant

E_{ji}/I_{ji} = Vector of effluent/influent ratios for n pollutants for i^{th} effluent (influent) in j^{th} plant

M_s = Plant characteristics

X_j = Prices of inputs for j^{th} plant

From this the marginal abatement cost is derived by taking the first derivative with respect to each pollutant in the effluent;

$$\frac{\partial C_j}{\partial E_{ji}} = \frac{\partial f(W_j, \frac{E_{ji}}{I_{ji}}, M_s, X_j)}{\partial E_{ji}} \text{ ------------------------------- } (2)$$

In empirically estimating cost functions, model specification can become an issue of concern. For example, Goldar et al. (2001) discuss the weaknesses of earlier studies by Rossi et al. (1979). They argue that in abatement cost functions, such as the one specified in equation (1) the output of the abatement activity is not appropriately defined. Goldar et al. (2001) correctly state that 'in cost function studies for manufacturing activity, cost is taken as a function of output of the activity and prices of inputs. It seems to us that a similar approach needs to be adopted also for specifying the cost function for pollution abatement'. In order to overcome this problem, instead of the effluent-influent ratio Goldar et al. (2001) use the difference between the pollution levels of influent and effluent water as a proxy of output of the abatement activity. The argument here is that abatement is a service activity where pollution levels are reduced. Thus, the actual output of the abatement activity is the reduction in pollution. A similar hypothesis was adopted by Hartman et al. (1997) in their study on air pollution.

In this study, we use a variant of the common econometric approach of estimating the marginal abatement cost. Instead of estimating a total abatement cost function, we estimate a more conventional total variable cost function. This is because in Sri Lanka, abatement costs associated with treatment plants are simply not available for most rubber factories. In most cases, there is very limited data on firms' treatment plants. To overcome this data problem, we use the total variable cost of the factory as the dependent variable instead of the total cost of abatement – as in previous studies. Output produced, input prices and effluent and influent ratios are used as independent variables. The only modification here to a conventional cost function is that we include pollution variables as arguments.

$$TVC_{it} = f(Y_{it}, W_{it}, \frac{E_{it}}{I_{it}}) \text{---}(3)$$

Where,

TVC_{it} = Total cost of the i^{th} factory in the t^{th} year
Y_{it} = Total quantity of output produced by the i^{th} factory in the t^{th} year
W_{it} = Input prices of the i^{th} factory in the t^{th} year
E_{it}/I_{it} = Effluent to influent ratio of the pollutant (Biological Oxygen Demand (BOD), COD, or Total Suspended Solids (TSS)) of the i^{th} factory in the t^{th} year

The use of the conventional specification of the cost function solves two problems. First, it eliminates the problem of collecting costs specific to the treatment plant. Secondly, it eliminates the problem of correctly specifying the output variable that should be included in the cost function.

Here, as in the earlier studies, the MAC is the first derivative with respect to each of the pollutants in the effluent. For instance, the MAC with respect to COD is given by,

$$MAC_{COD} = \frac{\partial TVC}{\partial (CODload)} \text{---}(4)$$

In order to estimate taxes, we still need to estimate MAC as a function of effluents. To do this, the MAC calculated for each factory using equation 4 is regressed on effluent concentration and wastewater volume generated by each factory. We then estimate the tax rate by keeping the wastewater volume at its mean value and replacing the effluent concentration with the Sri Lankan standard for effluents in water.

4. The Econometric Model

As discussed previously, we first estimate a total variable cost function for rubber production. The following empirical function is estimated:

$$\ln TVC_{it} = \beta_0 + \beta_1 \ln TP_{it} + \beta_2 \ln WR_{it} + \beta_3 \ln LP_{it} + \beta_4 \ln\left(\frac{COD_{eff}}{COD_{\inf}}\right)_{it} + \text{-----------------(5)}$$
$$\beta_5\left[\ln\left(\frac{TSS_{eff}}{TSS_{\inf}}\right)_{it} * \ln\left(\frac{COD_{eff}}{COD_{\inf}}\right)_{it}\right] + \beta_6 Type_i$$

Where,

TVC_{it} = Deflated total variable cost of i^{th} factory in t^{th} year in thousand LKR
TP_{it} = Total production of i^{th} factory in t^{th} year
WR_{it} = Deflated wage rate of i^{th} factory in t^{th} year
LP_{it} = Deflated price of rubber latex of the i^{th} factory in t^{th} year
COD_{eff} =COD concentration in the effluent of the i^{th} factory in t^{th} year
COD_{inf} =COD concentration in the influent of the i^{th} factory in t^{th} year
TSS_{eff} =TSS concentration in the effluent of the i^{th} factory in t^{th} year
TSS_{inf} =TSS concentration in the influent of the i^{th} factory in t^{th} year
$Type_i$ =Dummy variable representing major production type
(1=latex concentration, 0=otherwise)
ln = Natural log

In this specification, interaction terms of the pollution variables are included to capture the synergic effects of COD and TSS on reduction of cost. We specify the cost function in this fashion based on evidence from pollution abatement plants in the rubber industry. In addition, a dummy for the type of rubber output produced is also included because this has implications for total costs.

While various other functional forms of the cost function have been estimated in the literature, this log-log specification seems to be the most robust. Though, Goldar et al. (2001) estimated a translog cost function, various other studies have used the familiar Cobb-Douglas cost function (James and Murty, 1999; and Dasgupta et al, 2001). The use of Cobb-Douglas model also reduces the problem of multi-collinearity that is expected in a translog form.

The first derivative of the above function (5) with respect to COD_{eff} gives the MAC with respect to COD for each factory. For computing marginal cost of abatement for a unit reduction in pollution concentration, the marginal cost of reducing the effluent load is divided by the wastewater volume (James and Murty, 1999). Since the MAC is for a reduction of COD load, it is expected to have a negative sign and is given by:

$$MAC_{it} = \frac{\partial TVC}{\partial(COD_{load})} = \frac{\partial TVC}{\partial COD_{eff}} * \frac{1}{WW_{it}} = -\left[\frac{\beta_{COD}}{COD_{eff}} + \frac{\beta_{INT}}{COD_{eff}} * \ln\left(\frac{TSS_{eff}}{TSS_{\inf}}\right)\right]_{it} * TVC_{it} * \frac{1}{WW_{it}} \text{--------(6)}$$

Where,

WW_{it} = waste water volume of i^{th} factory in t^{th} year

The estimated MAC for each factory is then regressed with the effluent concentration and the waste water volume (in order to control for volume) of each factory to obtain the marginal abatement cost function. We follow Murty et al. (2006) in specifying a log-log functional form for the MAC.

$$\ln MAC_{it} = \alpha_0 + \alpha_{COD} \ln(COD_{eff})_{it} + \alpha_{WW} \ln WW_{it} \text{ --- (7)}$$

Equation (7) provides us with estimates of the coefficients for COD and wastewater volume. Using these coefficients and replacing COD_{eff} with the standard for COD (400mg/l), and setting wastewater volume (*WW*) at its mean value, allows us to estimate the tax rate necessary to make the firms comply with the standard.

5. Data and the Study Area

Rubber is grown in twelve administrative districts in Sri Lanka but amongst these three dominate – Kalutara, Kegalle and Ratnapura – which contain 90 per cent of rubber extents (Ministry of Plantation Industries, 2005). Rubber is produced large-scale mainly in these three districts, in which the big plantation companies are concentrated, while small rubber growers are scattered all over the country.

Though, there are 104 rubber factories that produce rubber, many have in recent years been kept in disuse by plantation companies as part of cost-cutting policies. Instead, plantation companies prefer 'central processing' wherein they transport all the rubber latex produced to the largest factory they own. Such a concentration of production activity only increases the impact of pollution. This study therefore selected 62 factories presently in operation.

Data were collected through interviews using a pre-tested questionnaire. We also obtained information from the records maintained at the factories (the distribution of studied factories is contained in Table 3). Cost and other data pertaining to three years (2003, 2004 and 2005) were collected from these records.

The cost data obtained from the factories had to be modified appropriately for the analyses. We obtained data on the wage rate by dividing the total wage bill of the factory by the number of laborers employed. Some factories purchased latex while others used latex from their own plantations. In the case of the latter, the cost of production per kilogram of latex was treated as its price.

The pollution data (BOD, COD, TSS and Ph levels of effluent and influent) were measured by collecting waste water samples in 2006, which were analyzed at the Rubber Research Institute of Sri Lanka. However, data on volume of wastewater generated was available from factories for 2003, 2004 and 2005. Since, COD and other pollution indicators are measured in mg/l, they were then estimated in kiloliters for 2003, 2004, 2005 based on data on total volume of wastewater.

Our data shows that waste generated by rubber factories varies greatly (descriptive statistics in Table 4). As Table 4 shows, the annual wastewater volume generated by rubber factories varies from 914 to 155,977 kiloliters. The scale of operation of factories also varies a great deal as is evident from the total cost of production. The pollution generation by the average firm, as indicated by average characteristics of influent water quality, was found to be far above environmental standards. For instance, the average firm exceeds COD and BOD standards by 3700mg/l and 1000mg/l respectively.

6. Results and Discussion

6.1 Estimating Marginal Abatement Costs of Pollution Reduction

In our dataset, we have data on costs and other variables pertaining to three years in 62 factories. Thus, the full data set was regressed as a panel. The regression was carried out assuming both random effects and fixed effects models. The Hausman test was used to select between the random effect model and the fixed effect model. A significant Hausman test statistic (17.88) at 1% level indicated a better fit with the random effects model, which was subsequently used in the final analyses (Table 5).

There are three main indicators of pollution: BOD, COD and TSS. BOD was removed from the regression as it is correlated with COD (Dasgupta et al., 2001). However, TSS and COD did not show serious multi-collinearity and therefore were included together in the regression as predictors. The Variance Inflation Factors (VIF) was close to unity indicating that there is no serious multi-collinearity.

The final model includes the ratio of COD effluent to COD influent and the interaction between this COD ratio and the ratio between TSS effluent to TSS influent. When abatement increases, that is when the factories increases their abatement activities, these ratios are expected to go down as the COD (or TSS) concentration in the effluent is decreased. Alternatively, the more the pollution permitted, the lower the costs borne by the factory. Hence, the coefficients on the pollution variables are expected to be negative. By definition, the cost functions are non-decreasing in input prices and thus the signs of input prices are expected to be positive.

The random effects estimation of the cost function is presented in Table 5. The quantity of production (TP) was significant at 1% while wage rate (WR), COD ratio, and interaction between COD ratio and TSS ratio are significant at the 5% level. However, the price of latex (LP) is significant at 10%. The TP and input prices have the expected positive sign indicating increases in production and input prices would increase costs. The pollution variables have the expected negative sign indicating that costs increase as the firms try to reduce the pollution.

As discussed earlier, the partial derivative with respect to COD load in the effluent gives us the marginal abatement cost of the firm with respect to COD. For computing the marginal cost of a reduction of COD concentration in the effluent, the marginal cost of reducing the COD effluent load was divided by the average volume of wastewater (James and Murty, 1999). Accordingly, the marginal abatement corresponding to a decrease in COD is given by:

$$MAC_{it} = \frac{\partial TVC}{\partial (COD_{load})} = \frac{\partial TVC}{\partial COD_{eff}} * \frac{1}{WW_{it}} = -\left[\frac{-0.162198}{COD_{eff}} + \frac{-0.0704801}{COD_{eff}} * \ln\left(\frac{TSS_{eff}}{TSS_{\inf}}\right)\right]_{it} * TVC_{it} * \frac{1}{WW_{it}} \quad \text{----(8)}$$

The total variable cost (TVC) in the above equation is in thousand rupees and waste water (WW_{it}) is in kiloliters. In order to convert it to rupees, the estimated MAC has to be multiplied by 1,000 and to convert the kiloliters to liters, the MAC has to be divided by 1,000. Hence, the MAC is in rupees per milligram as COD is in milligrams per liter. However, since the cost has been deflated for the panel regression, the MAC calculated above was multiplied by the GDP deflator in order to bring it back to 2005 rupees.

Figure 2 depicts how the MAC varies with COD concentration in the effluent when all other variables are kept at their mean levels in the above equation. As expected, it shows that the MAC increases with a reduction in the COD concentration in the effluent. This indicates that the increase in cost per unit decrease in COD concentration is higher when the level of COD in waste water is lower.

Table 6 presents descriptive statistics on the estimated MAC. A large variation in the estimated MAC is observed — an indication that factories are not using efficient or cost minimizing pollution abatement technologies. This is expected because of the use of inefficient command and control instruments in Sri Lanka.

6.2 The Pollution Tax

As previously discussed, in order to estimate the effluent tax rates that will lead rubber manufacturers to comply with Sri Lankan pollution control standards, it is necessary to first estimate the MAC as a function of pollution. Thus, the MAC calculated in equation (8) for each firm is used as data in the next step.

We regressed the estimated MAC on waste water volume and the COD concentration in the effluent (Table 7). In this estimation, the dependent variable, the MAC, is in rupees per milligram, and the independent variables are WW_{it} or the volume of wastewater generated by the i^{th} firm and COD_{eff}, which is the COD concentration (mg/l) in the effluent of the i^{th} firm. The double log form was found to be the best functional form and is thus reported here. Though, a more flexible translog form was also attempted, the cross product terms in the translog form proved to be insignificant indicating that the Cobb-Douglas form fits the data well. Murty *et al* (2006) use the same functional forms in estimating the shadow prices (marginal cost of abatement) of pollutants. A significant negative sign of the coefficient on COD_{eff} implies that the higher the pollution abatement, the higher the marginal cost. Our results show a significant and negative sign with respect to wastewater volume. This implies that the marginal cost falls with the increasing pollution load and hence scale economies are evident in pollution abatement.

In order to estimate the effluent tax rates necessary for the firms to comply with the pollution standards set out by the CEA, COD_{Eff} is replaced by the standard for COD (400mg/l) in equation 7 and its value estimated.

The tax rate necessary to make the firms to comply with the effluent standard of 400mg/l (COD) is LKR 0.00026 per milligram. We then obtain the tax rate per 100 grams of effluent concentration by multiplying the MAC estimate by 100 x 1,000 (since 1,000mg=1g). Thus, we estimate that a tax rate of LKR 26 per 100g of COD concentration per year would be sufficient to ensure compliance with Sri Lanka's effluent standards.

Another way to think about this tax is by estimating the tax rate per rubber output. In order to calculate the tax rate per kilogram of output, first the average excess COD present in effluent waste water was calculated. This was multiplied by the tax rate (LKR 0.00026/mg) to derive the total tax liability for the average firm. This was divided by the average production to yield the tax rate per kilogram of output. Expressed in terms of output, the tax rate stands at LKR 0.05 per kg of output per year.

Another issue of interest to us is the financial implications of a pollution tax. Thus, we were interested in gauging the total cost due to tax in relation to firms' revenues. As pollution taxes will have to be paid only by those firms recording effluent concentration levels more than the standard (Table 8), taxes were calculated only for these. We find that industry wide, an average of 8.6 per cent of the total annual turnover would be payable as pollution tax to comply with environmental standards. We arrived at this figure by dividing the taxes estimated for the average excess effluent concentration in the sample by the average revenue in the sample. In order to verify the distributional impacts of taxes, we undertook the same calculations for firms (with COD above established limits) with the highest and the lowest revenues. Our analyses suggest that the tax burden for the largest firm would be 5.2 per cent while it could be as high as 25 per cent for small firms.

7. Conclusions

The rubber industry is one of the most polluting in Sri Lanka as it is responsible for large volumes of effluent. Our data suggests that almost half the factories do not meet the standards set for BOD, COD and TSS.

In this study, we attempt to gauge the benefits of an economic instrument such as a tax on pollutants to promote environmental compliance by rubber producing firms. We estimate the tax in a two-step process: we first estimate the marginal abatement cost of reducing pollution to rubber firms and then the equivalent tax that would let them meet environmental standards. Following this, we also estimate the burden of any such tax and its financial implications for different firms.

The average tax rate that would motivate firms to comply with current environmental standards is LKR 26 per year for every 100 grams of COD in the effluent. Such a tax would amount to 8.6 per cent of the total annual turnover of the rubber industry. However, the burden of taxes can be as high 25 per cent for smaller firms. Thus, if a tax is levied, some form of support may be considered for smaller firms. – this issue requires careful exploration.

For any pollution tax to be successful there needs to be careful monitoring of effluent levels. Even with the current standards system monitoring is essential, but brings with it no revenue to the government. Thus, the CEA itself may be better motivated if it were to shift towards a tax based monitoring system. Recently the CEA decentralized some of its pollution control activities to reduce its workload and costs. With the necessary legal authority, regional agencies could help the CEA implement a tax system to control pollution. How the legal framework in Sri Lanka can be used to establish a pollution tax needs further examination. In addition, as rubber is an exported commodity, it is extremely price sensitive. The effect of a pollution tax on rubber exports also need to be studied — however, rubber prices are currently very attractive in the world market and producers, who are deriving large profits should be able to bear a tax.

It should be noted that one advantage of the tax-based approach is that it may motivate polluting firms to make use of the effluents. There have been attempts to retrieve important chemicals from the effluent such as *Qubrachitol* and research has shown that effluent water from the rubber production process can be used as partial fulfillment of fertilizer required by certain crops. Moving towards a tax based system may increase the momentum towards effluent use.

There is considerable scope for improvement in our preliminary analysis. We have attempted to study the robustness of the MAC in terms of model specification; however, it would be useful to undertake other such econometric studies since this would make the design of a pollution tax more credible. In order to undertaken better studies, a good panel data set is of utmost importance. The Central Environmental Authority is best suited to take leadership in obtaining such data.

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TABLES

Table 1: General standards and tolerance limits

Receiving substrate or medium		Tolerance limits			
		BOD (mg/l)	COD (mg/l)	pH	TSS (mg/l)
Inland surface waters		30	250	6.0 - 8.5	50
CETP		200	600	6.0 - 8.5	500
Marine coastal areas		100	250	-	150
Textile industries to inland surface waters		60	250	6.5 - 8.5	50
Irrigation purposes		250	-	5.5 - 9.0	2100 (TDS)
Rubber to inland surface waters	Latex concentrate	60	400	6.5 - 8.5	100
	Standard Lanka rubber /Crepe rubber / RSS	50	400	6.5 - 8.5	100
Tanning industry	Inland surface waters	60	250	5.5 - 9.0	100
	Marine coastal areas	100	300	5.5 - 9.0	150

Source: Herath and Randeni, 2003
RSS: Ribbed Smoked Sheets; CETP: Common Effluent Treatment Plants

Table 2: Effluent parameters generated from various rubber production processes

Parameter	RSS	Crepe	TSR	Latex Concentrate	Dipped products	Tolerance limit
PH	4.9	5.0	5.7	3.7	7.2	6.5-8.5
Settable Solids(mg/l)	50	45	155	100	200	
Suspended Solids(mg/l)	140	130	237	190	241	100
Total Solids (mg/l)	3745	3500	1915	7576	2457	1500/1000
COD (mg/l)	3300	3500	2740	6201	2011	400
BOD (mg/l)	2630	2500	1747	3192	1336	50/60
Ammonical Nitrogen (mg/l)	75	80	66	401	126	300/40
Total Nitrogen (mg/l)	500	550	147	616	180	300/60
Sulphates (mg/l)				1610	72	1000

Source: Sena Peiris (http://www.ens.gu.edu.au/ciep/CleanP/CPBook/Chapt11.pdf)
TSR: Technically Specified Rubber

Table 3: Location of factories studied

District	No. of factories studied
Kalutara	26
Kegalle	12
Ratnapura	12
Colombo and Gampaha	6
Galle	6
Total	62

Table 4: Summary statistics of the factories studied (2005)

	Unit	Minimum	Average	Maximum
Total cost	Million LKR	1.03	38	392
Turnover	Million LKR	0.98	210	7429
Wastewater volume	Kilolitres	914	24664	155977
Input prices				
Wage rate	LKR/man day	103.50	180.15	556.23
Latex price	LKR/kg	86.29	100.55	107.67
Influent characteristics				
BOD	Mg/l	20	1471.4	4500
COD	Mg/l	200	3218	10000
TSS	Mg/l	30	333.4	860
PH		1.6	5.4	7.1
Effluent Characteristics				
BOD	Mg/l	2	1062.5	5100
COD	Mg/l	20	2010	8800
TSS	Mg/l	4	242.9	860
PH		1.6	5.9	8.1

Table 5: Panel data estimates of the total variable cost function (random effects model)

	Coefficient	S.E.	Z	p>z
ln TP	0.8335495***	0.0987651	8.44	0.000
ln WR	0.4576272**	0.1813888	2.52	0.012
$\ln(COD_{EFF}/COD_{INF})$	-0.162198**	0.0761507	-2.13	0.033
$\ln[(COD_{EFF}/COD_{INF})*(TSS_{EFF}/TSS_{INF})]$	-0.0704801**	0.0307498	-2.29	0.022
ln LP	0.2480432*	0.1296468	1.91	0.056
Type of production	0.0299475	0.4119287	0.07	0.942
Constant	-0.1701658	0.6543045	-0.26	0.795
R^2 within group	0.4537			
R^2 between group	0.4110			
R^2 overall	0.39			
Wald chi2(5)	101.3 (prob>chi2=0.0000)			
N	137			

*** significant at 1%, ** significant at 5% and * significant at 10%
TP: Total Production, WR: Wage Rate, LP: Price of Latex R^2: Goodness of Fit

Table 6: Descriptive statistics of the Marginal Abatement Costs estimated

	MAC (Rs. at 2005 prices/100g)
Minimum	1.03
Mean	96.72
Maximum	1089.21

Table 7: Least square estimates for the marginal abatement cost function

	Coefficient	S.E.	't' value	p>t
lnWW	-1.241**	.111	-11.164	.000
lnCODeff	-.723**	.050	-14.338	.000
Constant	8.283**	1.106	7.490	.000
F	177.56			
Adj. R2	0.75			

** Sig. at 5%

Table 8: Deviation from the standard

Effluent parameter	Percentage of factories deviated from the standard
BOD	56.7
COD	45
TSS	50

FIGURES

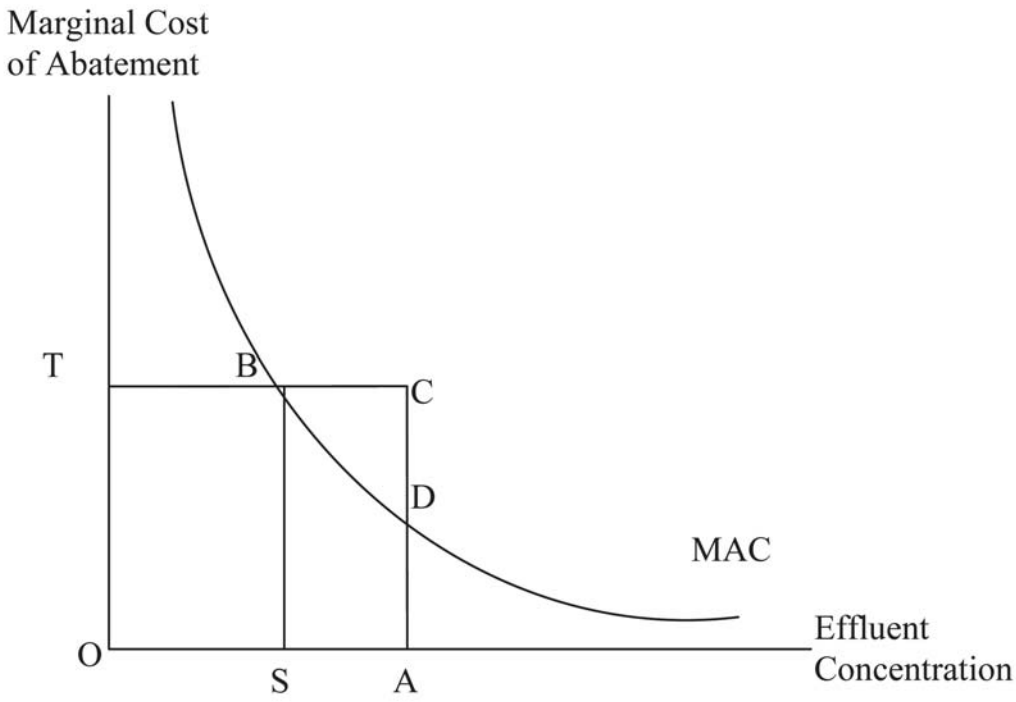

Figure 1: The taxes standards approach
Source: James and Murty, 1999

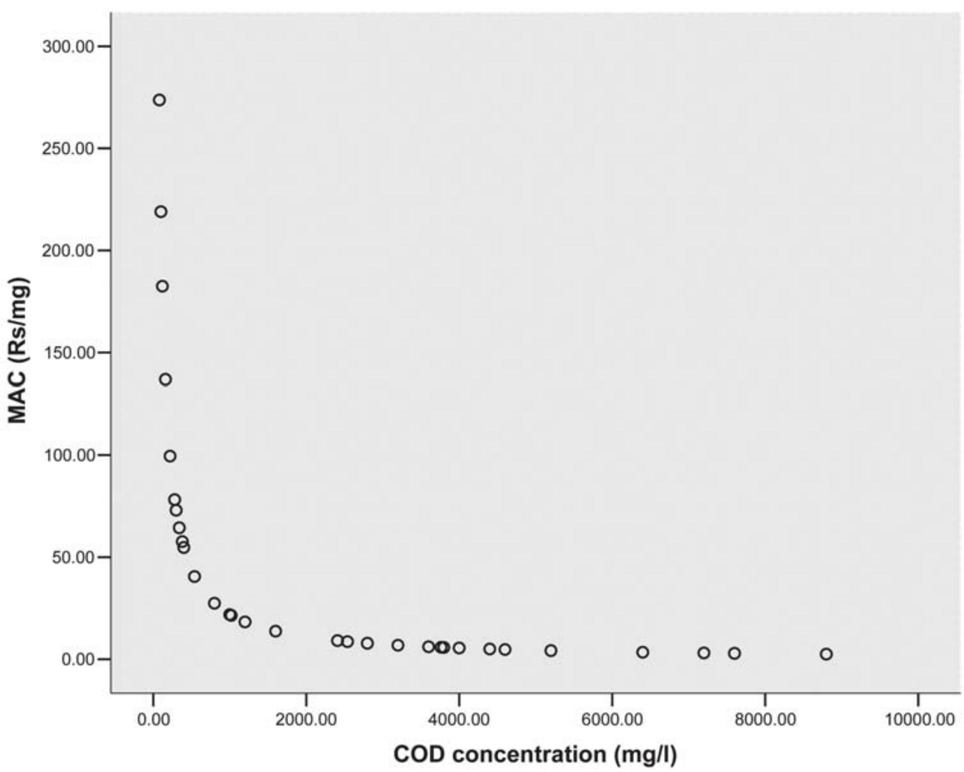

Figure 2: Marginal costs of abatement with the COD concentration in the effluent

Annex 1

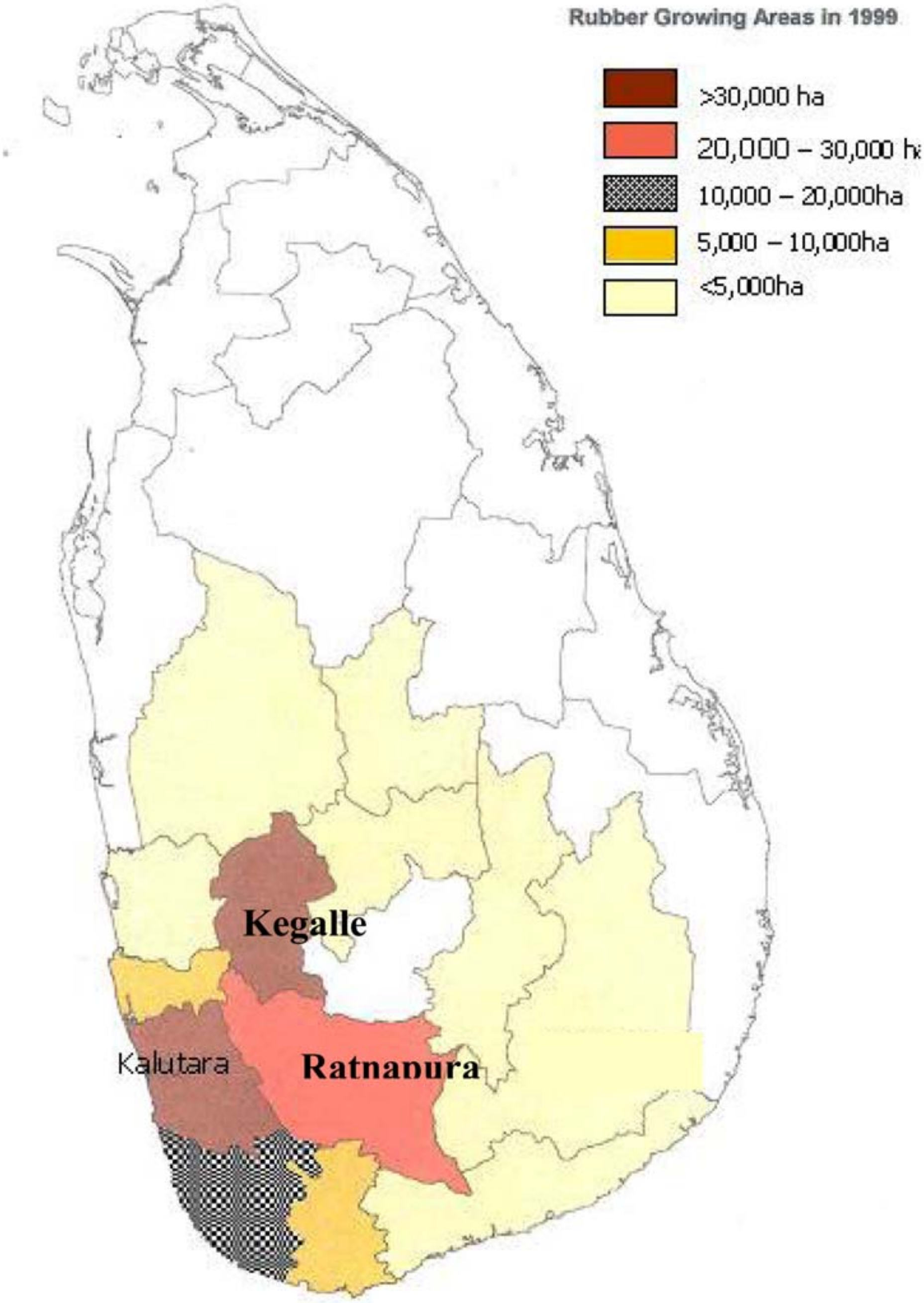

Figure A1: Rubber growing regions in Sri Lanka
Note: The three major regions are named

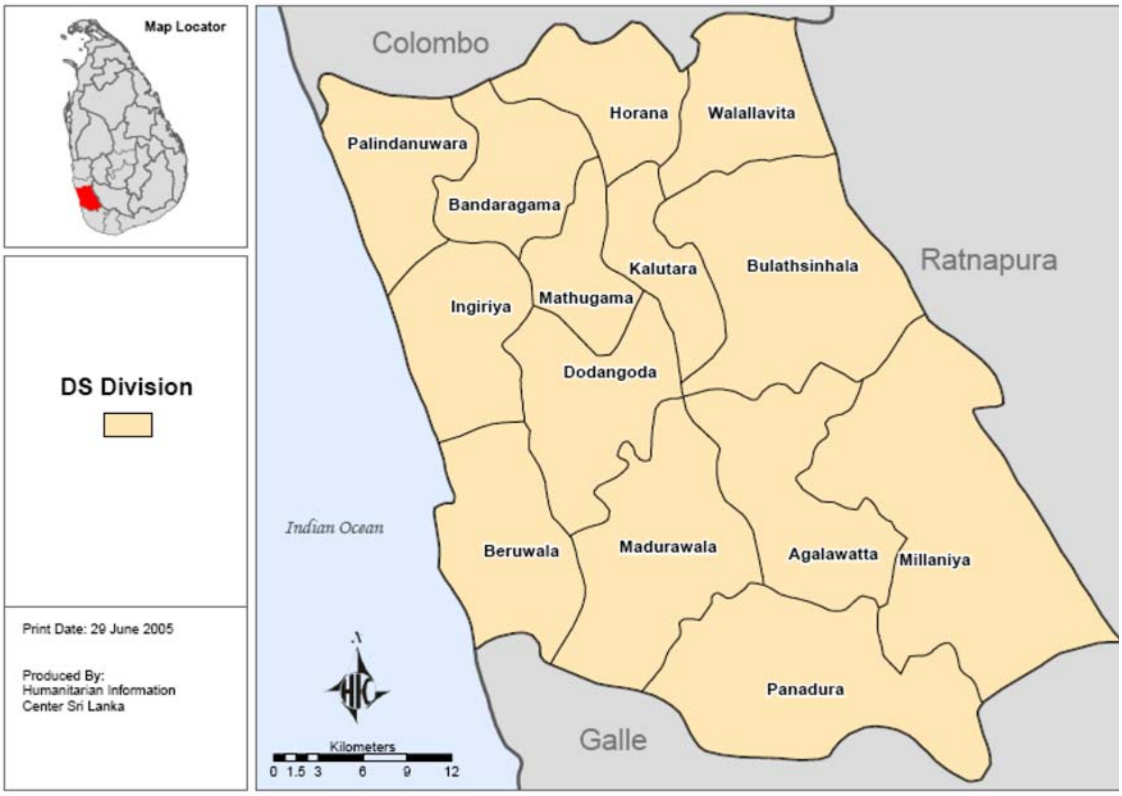

Figure A2: Administrative map of Kalutara District
Source: Downloaded at http://www.humanitarianinfo.org/srilanka/catalogue/

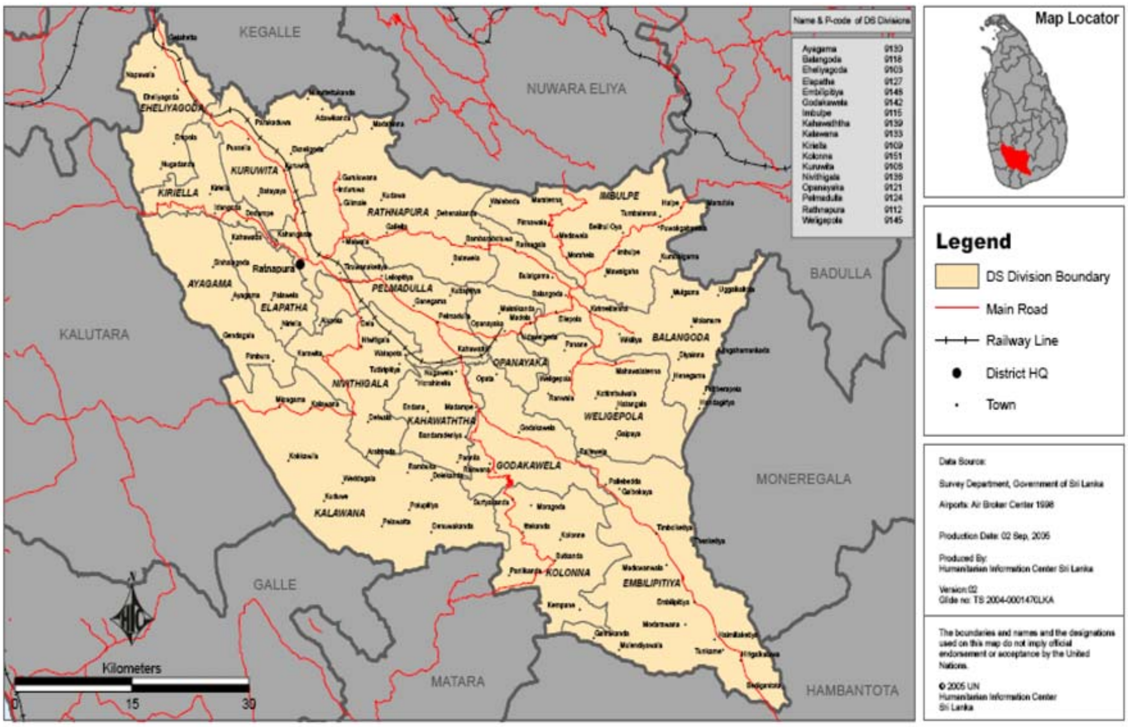

Figure A3: Administrative map of Ratnapura District
Source: Downloaded at http://www.humanitarianinfo.org/srilanka/catalogue/

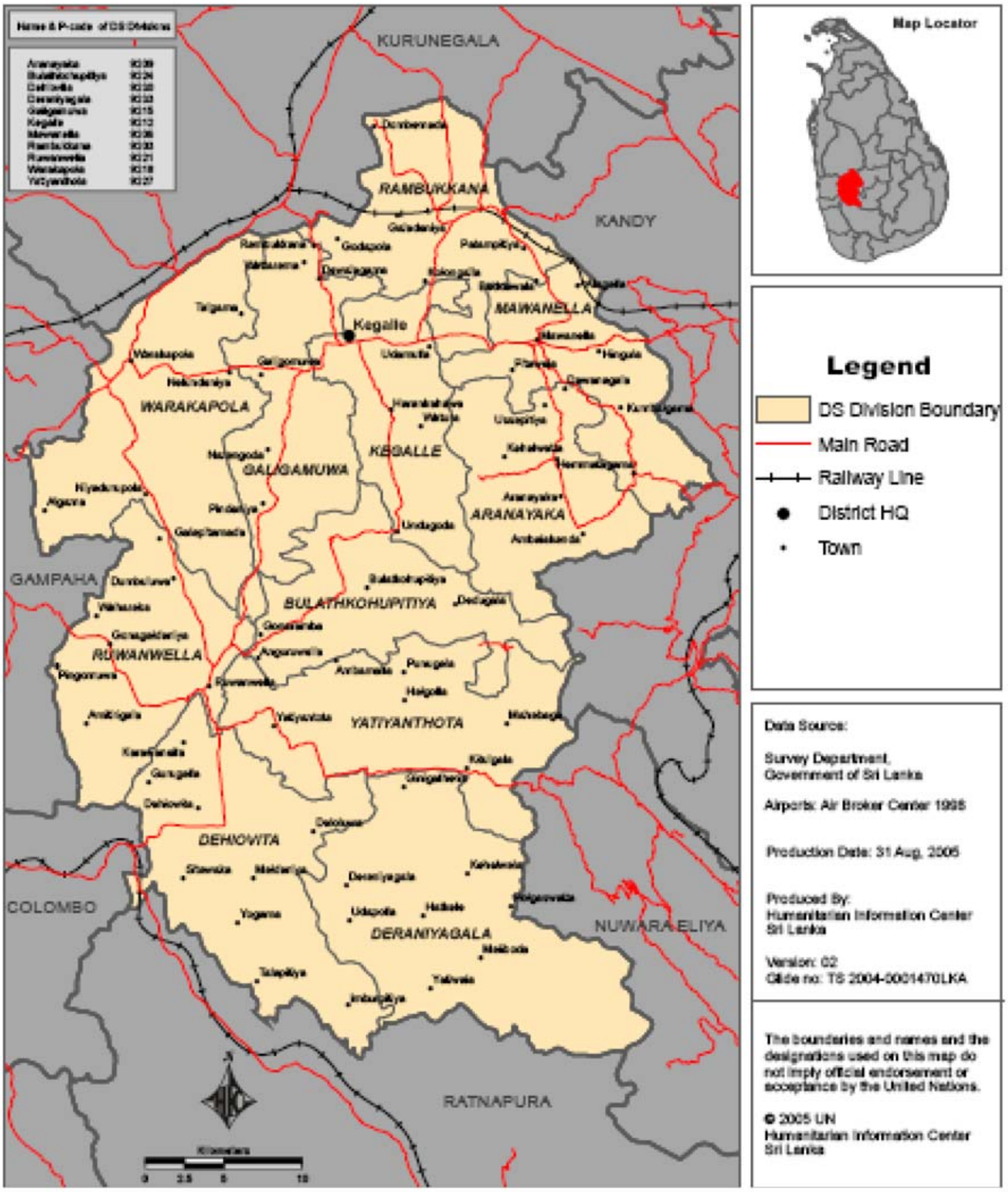

Figure A4: Administrative map of Kegalle district

Source: Downloaded at http://www.humanitarianinfo.org/srilanka/catalogue/

Annex 2

RUBBER RESEARCH INSTITUTE OF SRI LANKA
AND
SOUTH ASIAN NETWORK FOR DEVELOPMENT AND ENVIRONMENTAL ECONOMICS (SANDEE)

Questionnaire Survey on Rubber industry

Influent Sample Collected (Y / N).
Effluent Sample Collected (Y / N).
Name of the Enumerator ……………………….
Sample No …………………………………...
Date …………………………………………….

1. General information

1.1 Name of the organization…………………………………………………...
1.2 Managing company…………………………………………………………….
1.3 Address………………………………………………………………………
1.4 GN Division……………………………………………………………………
1.5 District…………………………………………………………………………….

2. Details of production

2.1 Type of out put produced (tick the appropriate box)

Latex crepe ☐ Sole Crepe ☐ Scrape crepe ☐ centrifuged latex ☐
RSS ☐ Dipped product ☐ other ………………………

3. Out put

3.1 State quantity of out put produced in last five years.

Year	Latex crepe	Scrap crepe	Sole crepe	RSS	Dipped product	Centrifuged latex	NSA	Other (specify)
2005								
2004								
2003								
2002								
2001								

3.2 Annual costs and turn over

Year	Total cost (Rs)	Annual turn over of Estate (Rs)
2005		
2004		
2003		
2002		
2001		

3.3 Stock at the end of the year

Year	Latex crepe	Scrape crepe	Sole crepe	RSS	Dipped product	Other (specify)
2005						
2004						
2003						
2002						
2001						

4. Input usage

4.1 Estate

4.1.1 Labor & Staff

Year	Labor			Staff	
	Man days	Wage rate	Cost	No of Staff	Cost
2005					
2004					
2003					
2002					
2001					

4.1.2 Other input of estate

Year	Land		Fertilizer		Chemicals	
	Mature	Immature	Qty (kg)	Cost (Rs)	Volume	Cost (Rs)
2005						
2004						
2003						
2002						
2001						

4.1.3 Clones cultivated (Extent under each clone in Ha)

Year	RRISL 100	RRISL 101	RRISL 102	RRISL 103	PB86	Other (Specify)
2005						
2004						
2003						
2002						
2001						

4.2 Factory

4.2.1 Input usage

Year	Labor			Chemicals		Fuel			
	Man days	Wage rate	Cost	Vol	Cost	Amount	Cost	Power Cost	Water (Rs/year)
2005									
2004									
2003									
2002									
2001									

4.3 Expenditure on man power

Number of Employees

Year	Estate		Factory		Office		
	Casual	Permanent	Casual	Permanent	Casual	Permanent	Total wage bill / year for the whole
2005							
2004							
2003							
2002							
2001							

4.4 Rent

- Do you pay rent for factory / estate? **Y / N. ……………**
- If yes;

Year	Area rented (Ha)	Rent pre unit area
2005		
2004		
2003		
2002		
2001		

5. Capital stock
5.1 value of capital stocks in the estate.

Year	Val. of Buildings	Plant and Machinery	Vehicles	Other	Total
2005					
2004					
2003					
2002					
2001					

5.2 Depreciation rates used.
- For buildings. …………………………
- For plants and machinery's. ………………………

Part 2.
Water pollution abatement.

6.0 Do you operate a treatment plant? **Y / N.**

- If yes go to **7.**
- Else go to **8**.

7.1 General technical details
7.1.1 Total capacity of the factory………………………………………………………
7.1.2 Avg. running capacity / per day (25%, 50%, 75% other). ………………………..
7.1.3 Avg. volume of untreated waste water generated per day………………………..
7.1.4 Nature of treatment (primary, secondary, tertiary)……………………………….
7.1.5 Total cost of the investment (Rs)…………………………………………………

7.2 Economic details
7.2.1 Year of the installation of the treatment plant………………………………….
7.2.2 Value of capital stock of treatment plant

Year	Value	Year	Value	Year	Value
2005		2003		2001	
2004		2002			

7.2.3Number of people employed in treatment plant.

Year	Engineers	Supervisors	Skilled labors	Unskilled labors	Other
2005					
2004					
2003					
2002					
2001					

7.2.4 Annual labor cost (Rs)

Year	Salary (Supervisor, Engineer etc connected to ETP)	Total labor cost
2005		
2004		
2003		
2002		
2001		

7.2.4.1 Breakdown of labor cost in 2005

Item	Man days 2005	Total labor cost
Repairs		
Cleanings		
Other		

7.2.5 Annual maintenance expenditure (Excluding wages).

Year	Maintenance exp.
2005	
2004	
2003	
2002	
2001	

7.2.6 Annual material cost (Rs)

Year	Material cost
2005	
2004	
2003	
2002	
2001	

7.2.7 Annual material cost (Fuel & Power).

Year	Energy cost
2005	
2004	
2003	
2002	
2001	

7.2.7.1 Electricity consumption

	Aerator	Sludge pump	Effluent pumping
No of Motors			
Horse power			
Running duration / day			

7.2.7.2 Rate at which electricity is change (Rs / unit)……………………………………..
7.2.8 What is the total annual expenditure for the treatment plant

Year	Cost (Rs)
2005	
2004	
2003	
2002	
2001	

7.2.9 Where does the treated water discharge?
Stream ☐ River ☐ Paddy field ☐ other ☐

7.2.10 Do you have any complaints on environmental pollution by the factory?
Y / N
If yes,

7.2.10.1 From where, Factory ☐ Villagers ☐ Your workers ☐
Other ☐

7.2.10.2 Why did your company decide to invest on a treatment plant………………
……………………………………………………………………………………………

8.0. Please fill for those factories that do not have a treatment plant

8.1 Why have you not invested in a treatment plant?
No complaint ☐ High cost ☐ Low profitability from rubber ☐
Don't knew about treatment ☐ Plants not important ☐
Other………………………………………………………………………………………….
8.2 Do you think that effluent has any environmental hazard? Y / N.
8.3 Are there any complaints on environmental pollution by your factory Y / N.
IF yes, from where,
Within factory ☐ villagers ☐ others ………………………………..

8.4 What was the complaint?
- Smell…………………
- Contaminated water ways…………………..
- Increased disease incidences ……………….
- Any other……………………………………………………………………….

9.0 Influent and effluent characters (Fill the table below, after the sample is analyzed)

9.1 Influent quality

Date (collected)	Date Analyzed	BOD	COD	PH	TSS	TS

9.2 Treated effluent quality

Date (collected)	Date Analyzed	BOD	COD	PH	TSS	TS

10. Environmental regulations

10.1 Agencies or persons (government / private) with whom the firm has been interacting in the recent past in connection with the pollution abatement

1………………………………………………………………………………………..
2………………………………………………………………………………………..
3………………………………………………………………………………………..

10.2Number of court cases about air/ water pollution by CEA, Local people, NGO, etc against factory.

Year	CEA	Local people	NGO	Other (specify)
2005				
2004				
2003				
2002				
2001				

10.3 Legal expenses of the firm to deal with court case for air/ water pollution.

Year	Expansion	Compensation	total
2005			
2004			
2003			
2002			
2001			

10.4 Number of visits to factory by CEA for monitoring pollution.

Year	No of visits
2005	
2004	
2003	
2002	
2001	

10.5 Fine / penalty imposed / compensation paid for non-complying with the standards of air water pollution.

10.6 Subsidy, depreciation, allowances, and tax concessions received from the government for controlling pollution.

Year	Subsidies	Dep. Allowances	Tax concessions	Loan scheme